



# Conodonts in Ordovician biostratigraphy

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The long time interval after Pander's (1856) original conodont study can in terms of Ordovician conodont biostratigraphical research be subdivided into three periods, namely the *Pioneer Period* (1856–1955), the *Transition Period* (1955–1971) and the *Modern Period* (1971–Recent). During the pre-1920s, the few published conodont investigations were restricted to Europe and North America and were not concerned about the potential use of conodonts as guide fossils. Although primarily of taxonomic nature, the pioneer studies by Branson & Mehl, Stauffer and Furnish during the 1930s represent the beginning of the use of conodonts in Ordovician biostratigraphy. However, no formal zones were introduced until Lindström (1955) proposed four conodont zones in the Lower Ordovician of Sweden, which marks the end of the Pioneer Period. Because Lindström's zone classification was not followed by similar work outside Baltoscandia, the time interval up to the late 1960s can be regarded as a Transition Period. A milestone symposium volume, entitled 'Symposium on Conodont Biostratigraphy' and published in 1971, summarized much new information on Ordovician conodont biostratigraphy and is taken as the beginning of the Modern Period of Ordovician conodont biostratigraphy. In this volume, the Baltoscandic Ordovician was subdivided into named conodont zones, whereas the North American Ordovician succession was classified into a series of lettered or numbered faunas. Although most of the latter did not receive zone names until 1984, this classification has been used widely in North America. The Middle and Upper Ordovician Baltoscandic zone classification, which was largely based on evolutionary species changes in lineages and hence includes phylozones, has subsequently undergone only minor changes and has been used slightly modified also in some other regions, such as New Zealand, China and eastern North America. The great importance of conodonts in Ordovician biostratigraphy is shown by the fact that conodonts are used for the definition of two of the seven global stages, and seven of the 20 stage slices, now recognized within this system. □ *Conodonts, global biostratigraphy, Ordovician, research history.*

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Along with graptolites, conodonts are now considered to be the regionally and locally most useful index fossils in the Ordovician. They are generally well represented in, and easily extracted from, most calcareous marine sediments and are also present in many shales. They are particularly useful biostratigraphically in the vast carbonate-dominated continental platform successions in which graptolites tend to be sparse and represented by species of only limited biostratigraphical utility. Although both these index fossil groups have sometimes been considered facies fossils, the zone classifications based on each group complement each other. Furthermore, there are currently more than 100 direct ties between conodont and graptolite zones as summarized by Bergström (1986).

Conodonts were first described more than 150 years ago by Pander (1856), but their great utility as zone fossils in the Ordovician was not recognized until some 100 years later by

Lindström (1955). For convenience, we distinguish three periods of Ordovician conodont biostratigraphical research, which we refer to as the *Pioneer Period* (1856–1955), the *Transition Period* (1955–1971) and the *Modern Period* (1971–Recent). Each of these periods has its own characteristics and the transition from one period to another is marked by a special event that we regard as being of special significance in the history of Ordovician conodont biostratigraphical research. The purpose of the present study was to review major developments in conodont biostratigraphy and to list a selection of important investigations that have had a significant impact on the current status of conodont biostratigraphy around the world. The present paper is an outgrowth of an invited symposium presentation at the Second International Congress on Stratigraphy, which was held in Graz, Austria, in 2015 (Balini *et al.* this issue).

## The Pioneer Period

Out of biostratigraphical point of view, Pander's (1856) classic monograph is not very helpful in that he did not provide much information about the stratigraphical, or even geographic origin, of his Ordovician specimens. This has led to incorrect statements in the literature; for instance, even a well-known handbook states that the specimens came from Estonia, even if a careful reading of his text makes it clear that the Ordovician specimens came from the St. Petersburg region of Russia, where the source was a poorly consolidated glauconitic sand of Floian age (Bergström 1988), which is now known as the Leetsian horizon (or Stage). The few other Ordovician conodont occurrences described up to the 1920s, such as those of Hinde (1879), Wiman (1903), Smith (1907) and Hadding (1913), were based on specimens preserved on shale bedding planes and their potential as guide fossils remained unexplored. Systematic collecting through shale successions similar to those upon which Lapworth (1878) based on his graptolite zone biostratigraphy in South Scotland was not attempted anywhere and apparently, Pander's (1856) washing technique was not used on soft sediments. Conodonts remained as palaeontologic curiosities up to the 1920s, when extensive conodont research was initiated at several universities in the American Midwest. At the University of Missouri, Branson & Mehl (1933) and their students started a long and extensive programme involving isolation of conodonts by boiling of soft shales present in the local Palaeozoic succession and similar studies were carried out by Stauffer (1935a,b) at the University of Minnesota, Furnish (1938) at the University of Iowa, and Cullison (1938) at the School of Mines and Metallurgy in Missouri. This research resulted in the description of numerous new genera and species and general comparisons of the described faunas, but no formal conodont zones were proposed.

The rather accidental discovery by Graves & Ellison (1941) that conodonts could survive the breaking down of carbonate rocks by the use of acetic acid had a major impact on conodont investigations. Although the method did not become a standard preparation technique until the 1950s, its importance for conodont studies, including conodont biostratigraphy, cannot be overestimated because for the first time, it made it possible to obtain long series of productive samples through critical stratigraphical intervals. The comparatively late application of acid etching to isolate conodont

specimens from the rock matrix is somewhat surprising in view of the fact that it had been known for half a century that organic fossils, such as graptolites (e.g. Holm 1890; Wiman 1895), could be freed from the sediment by means of acid preparation. Although very representative conodont collections obtained by the acetic acid method were assembled around 1950 in North America (e.g. Branson *et al.* 1951) and Europe (e.g. Rhodes 1953, 1955), no formal zones were proposed. The use of conodonts in Ordovician biostratigraphy was still restricted to general comparisons of faunas and ranges of taxa, which were classified in terms of single element (form) taxonomy. Hence, the usefulness of conodonts for detailed local and regional biostratigraphy remained unexplored more than a century after the discovery of this enigmatic fossil group.

## The Transition Period

What may be considered the initial step in the history of the use of conodonts as zone index fossils in Ordovician biostratigraphy was the publication of Lindström's (1955) monograph on conodonts from the stratigraphically rather complete but quite condensed, dominantly calcareous, Lower Ordovician succession in south-central Sweden. Obviously influenced by Tjernvik's (1952) detailed trilobite investigation in the same interval (see also Tjernvik 1956), Lindström (1955) carried out virtually bed-by-bed sampling, and using acetic acid in the sample laboratory preparation, he assembled what is likely to have been the by far largest conodont collection existing at that time. His monograph not only includes description of nine new genera and 61 new species (all defined in single element taxonomy) but also, in it he formally established four named conodont zones in a stratigraphical interval ranging from the Tremadocian to the lower Dapingian in terms of current global stage terminology (Bergström *et al.* 2009). In modern species classification, these well-defined zones would be called the *Cordylodus angulatus*, *Paroistodus proteus*, *Oepikodus evae* and *Baltoniodus navis* zones. These zones were directly correlated with the trilobite zones established by Tjernvik (1952) in the same stratigraphical interval. We consider Lindström's (1955) study to be the beginning of a new era, here referred to as the *Transition Period*, in Ordovician conodont biostratigraphy.

For a few years, no additional Ordovician conodont zones were proposed anywhere in the world but in the following decade, Sergeeva (1964) and Viira (1966) introduced a slightly different set of

zones based on sections in the East Baltic. Their work also extended into somewhat younger strata than those initially investigated by Lindström (1955).

The only other region where extensive Ordovician conodont studies were carried out at this time was North America, where in the late 1950s local and regional investigations were initiated by faculty and students at several Midwest universities, such as The University of Missouri, University of Iowa and the Ohio State University. Conodonts from numerous formations, geographically ranging from the Great Basin in Utah and Nevada to the Appalachian Mountains in eastern North America, were investigated but no formal North American zone classification was proposed during the 1960s. Major reasons for this were the vast size of the continent, the most considerable thickness of many Ordovician successions, the regionally variable conodont species associations and the huge amount of taxonomic work required for classification of the largely undescribed faunas. Also in other parts of the world, no zone classification similar to that in Baltoscandia was introduced during this period. The focus in the 1960s was more on describing the conodont faunas and less on assessing their regional biostratigraphical significance.

A major event in the history of conodont research was the transformation of the formerly prevailing single element (form) taxonomy into a biologically sounder multi-element taxonomy. The first attempt to apply the latter consistently was in a study of the prolific Lexington Limestone fauna (Bergström & Sweet 1966). A similar taxonomic approach was used on some conodont taxa by Webers (1966) in a study on Sandbian and Katian faunas in Minnesota. However, it took several years before this approach became widely used in conodont taxonomy. Using this taxonomy, many generic and species names became obsolete but because the absence of named zones outside Baltoscandia, these name revisions never became a significant problem in the Ordovician conodont biostratigraphy.

Another event that came to have a profound influence on virtually all kinds of conodont research was the 1967 establishment of an informal conodont organization, the Pander Society. This society, which serves as an umbrella organization for all conodont workers, has been very active in sponsoring numerous national and international symposia on many aspects of conodont research, and to keep conodont workers informed about recent progress through comprehensive annual newsletters. Virtually, all the symposia have resulted in symposia volumes of lasting value.

## The Modern Period

### *The Columbus Symposium volume*

Such a Pander Society-sponsored symposium, held in May 1969 at the Ohio State University in Columbus, Ohio, resulted in a monographic volume entitled 'Symposium on Conodont Biostratigraphy' that was edited by Sweet & Bergström and published as a Memoir of the Geological Society of America. Chapters in this volume summarized the status of Cambrian to Triassic conodont biostratigraphy and contained a vast amount of new information, not least in the case of Ordovician. In view of its importance, we regard the publication of this volume as marking the beginning of the *Modern Period* in Ordovician conodont biostratigraphical research. Four relatively extensive papers in this volume summarized previously known data and much new information on Ordovician conodont biostratigraphy with focus on northern Europe and North America. In his paper on 'Lower Ordovician conodonts of Europe', Lindström (1971) described a Baltoscandic succession of 10 conodont zones in an interval ranging from the Tremadocian to the middle Darriwilian (Fig. 1). He used multi-element taxonomy and the zones were correlated with graptolite zones. His zones may be considered assemblage zones with the bases marked by the appearance of the zone index-species. No zone reference sections were selected but with relatively minor modifications, this zone succession has later been widely used not only in Baltoscandia but also in other parts of the world, such as Argentina and China.

In a paper entitled 'Lower Ordovician Conodonts in North America', Ethington & Clark (1971) presented a comprehensive review of Tremadocian and Floian conodont biostratigraphy in both the North American Midcontinent and the Great Basin in Utah and Nevada as well as in adjacent part of Canada. The conodont succession was subdivided into Faunas A through E based on the vertical ranges of 39 form species (Fig. 2). It would appear that the intervals of these Faunas are comparable to assemblage zones but no named zone designations were introduced.

A similar approach was used by Sweet *et al.* (1971), who subdivided the North American Lower to Upper Ordovician (Floian/Dapingian to Hirnantian) into 12 numbered Faunas (Fig. 3). Because of the incomplete knowledge of the conodont species succession, the existence of significant stratigraphical gaps and various correlation problems, they stated that it was premature to present a succession of

INTERNATIONAL SERIES	BALTIC SHIELD			Graptolite zones	Scandinavian subzones	Conodont zones		
	Series	Stages	Substages					
LLANVIRNIAN	MIDDLE ORDOVICIAN OR VIRUAN	Lasnamägian (C 1b)		<i>Didymograptus murchisoni</i>				
		Aserian (C 1a)						
ARENIGIAN	LOWER ORDOVICIAN OR OELANDIAN	Kundan (B III)	Aluoja (B III γ)	<i>Didymograptus bifidus</i>	<i>Isograptus gibberulus</i>	<i>Amorphognathus variabilis</i>		
			Valaste (B III β)					
			Hunderum (B III α)					
		Volkhovian (B II)	Langevoja (B II γ)	<i>Didymograptus hirundo</i>			<i>Microzarkodina parva</i>	
			Limbata beds (B II β)					<i>Paroistodus originalis</i>
			(B II α)					
Latorpian (B I)	Billingen (B I βγ)	<i>Didymograptus extensus</i>	<i>Phyllogr. angustif. elong.</i>	<i>Prioniodus evae</i>				
	Hunneberg (B I α)		<i>Phyllogr. densus</i>	<i>Didymogr. balticus</i>	<i>Prioniodus elegans</i>			
TREMADOCIAN	Ceratomyge beds (A III)		<i>Bryograptus</i>	<i>Tetragr. phyllograptoides</i>	<i>Paroistodus proteus</i>			
					<i>Paltodus deltifer</i>			
					<i>Cordylodus angulatus</i>			
	Pakerortian (A II)		<i>Dictyonema flabelliforme</i>					

Fig. 1. Lindström's (1971) Lower and Middle Ordovician (Tremadocian–Darriwilian) conodont zone succession in Baltoscandia. From Lindström (1971, fig. 1).

formal zones. For more than a decade (cf. Sweet & Bergström 1984), these numbered faunas were widely used as a kind of assemblage zones until Sweet (1984), in a paper on graphic correlation, introduced a series of named zone units (Fig. 4). Although the graphic correlation base data have not been published, no reference sections selected, and in some cases zone boundaries are defined only in terms of his graphic correlation system, these units have been widely used as faunal zones. Unfortunately, there are some problems with the definition and correlation of several of these zone units and a reassessment is clearly needed. In a later paper, Sweet (1988) referred to these units as biozones.

Based mainly on platform conodonts in the stratigraphically relatively complete upper Darriwilian to Hirnantian succession in Baltoscandia, Bergström (1971) introduced a zone sequence of five zones and 10 subzones (Fig. 5). Because these units were based on species in rapidly evolving lineages, they can be considered phylozones and phylosubzones. Each unit was defined in a precisely measured reference section in the Siljan region of central Sweden. Only key species were originally listed, but the complete faunas were much later recorded by Bergström

(2007). Although there have been minor modifications of this zone nomenclature, especially in regions lacking some of the key index-species, this zone succession has proved to be useful also in many regions far away from Baltoscandia. For instance, it turned out to be applicable to the upper Darriwilian and Sandbian successions in the eastern thrust belts of the Appalachian Mountains in eastern North America (e.g. Bergström 1971, 1973; Bergström *et al.* 1974; Bergström & Carnes 1976) where their use resulted in a greatly improved understanding of the age relations of many important formations. Whenever possible, the Baltic conodont zones were also applied to the Middle and Upper Ordovician successions in the Great Basin of western USA (Harris *et al.* 1979) and to the graptolite standard succession in the Marathon area in West Texas and elsewhere (Fig. 6; Bergström 1978).

### Newer developments

During the decades since 1971, extensive work on Ordovician conodonts and conodont biostratigraphy has been carried out in many parts of the world. Page limitations of the present contribution make it







SERIES	STAGE/SUBSTAGE	CONODONT ZONE	
CINCINNATIAN	GAMACHIAN	<i>A. shatzeri</i> Zone (1266)	
	RICHMONDIAN	<i>A. divergens</i> Zone (1210)	
	(1197)	<i>A. grandis</i> Zone (1177)	
	MAYSVILLIAN	<i>O. robustus</i> Zone (1157)	
	(1136)	<i>O. velicuspis</i> Zone (1104) UPPER LOWER	
MOHAWKIAN	(1065)	<i>B. confluens</i> Zone	
	"TRENT-ONIAN"	SHERMANIAN	<i>P. tenuis</i> Zone (1025) UPPER LOWER
		KIRKFIELDIAN	<i>P. undatus</i> Zone (989) (968)
	BLACK RIVERAN	ROCKLANDIAN	<i>B. compressa</i> Zone
		UPPER	<i>E. quadridactylus</i> Zone (927) (905)
		LOWER (=ASHBYAN)	<i>P. aculeata</i> Zone (809) (807)
WHITEROCKIAN	UPPER (= ± CHAZYAN)	<i>P. sweeti</i> Zone (757)	
	(680)	<i>P. friendsvillensis</i> Zone (680)	
	MIDDLE	<i>P. "pre-flexuosus"</i> Zone	
		<i>H. holodentata</i> Zone	
	LOWER	<i>H. sinuosa</i> Zone <i>H. altifrons</i> Zone	

Fig. 4. The classification by Sweet (1984) of the North American Darriwilian–Katian part of the Ordovician into series, stages and conodont zones. Numbers at the zonal boundaries are values in Sweet's graphic correlation system. Figure from Sweet (1984, fig. 2).

these regions (e.g. Knüpfner 1967; Serpagli 1967; Lindström & Pelhate 1971; Weyant *et al.* 1977; Paris *et al.* 1981; Ferretti & Serpagli 1991, 1999; Bergström & Massa 1992; Ferretti & Barnes 1997; Ferretti & Schönlaub 2001; Álvaro *et al.* 2007; Serpagli *et al.* 2007, 2008; Del Moral & Sarmiento 2008; Sarmiento *et al.* 2011; Ferretti *et al.* 2014c; Lehnert *et al.* 2016). Most of these studies deal with Katian and Hirnantian faunas and conodonts from some other parts of the Ordovician are incompletely known which is

likely due to the scarcity, or absence, of calcareous intervals in the successions.

*Siberia.* – The vast Siberian region has some of the most outstanding Ordovician outcrops in the world, but the published conodont information from these successions is somewhat limited and partly out of date. The pioneer work by Abaimova (1971) and Moskalenko (1973, 1983) was based on form taxonomy and as shown by the informative field trip guide of the important Kulyumbo River sections (Kanygin *et al.* 2006), the old conodont taxonomy has not yet been consistently updated in the Middle and Upper Ordovician. In her important review paper in English, Moskalenko (1983) presented useful information about the stratigraphical ranges of 17 index-species, many of which were used for subdivision of the Siberian Ordovician succession into 12 assemblage zones. This zone classification was recently updated by Sennikov *et al.* (2015) as illustrated in Figure 7. Although a few of these taxa have North American Midcontinent affinities, the Siberian faunas have their own provincial character which makes close correlation to North America difficult (cf. Dumoulin *et al.* 2002). There is virtual no similarity between the Siberian faunas and possibly equivalent ones from Baltoscandia so close correlation based on conodonts is not possible. Yet, as shown by, for instance, Dubinina (2000), Tolmacheva & Abaimova (2009), Tolmacheva *et al.* (2009) and Tolmacheva (2014), the Ordovician conodont succession currently recognized in Kazakhstan is rather similar to that in Baltoscandia although the Katian conodont faunas appear to be unstudied in Kazakhstan.

*New Zealand and Australia.* – Conodont faunas ranging in age from the Tremadocian to the Katian have been described from a variety of localities in the South Island of New Zealand (e.g. Zhen *et al.* 2009 and references therein). Because these faunas are dominated by species best known from Baltoscandia, it has proved possible to use the Baltoscandian conodont zone classification.

Ordovician conodonts have been described from a considerable number of localities in the vast Australian continent, which represent a variety of depositional environments (e.g. Zhen *et al.* 2003 and references therein). Whereas the deeper water faunas, such as that described from southern Tasmania by Burrett *et al.* (1983), are reminiscent of Baltoscandian faunas, the shallower water faunas from the continental platform, such as those from the Late Ordovician Cliefden Caves Limestone Group in central New South Wales (Zhen & Webby 1995), are more similar to North American

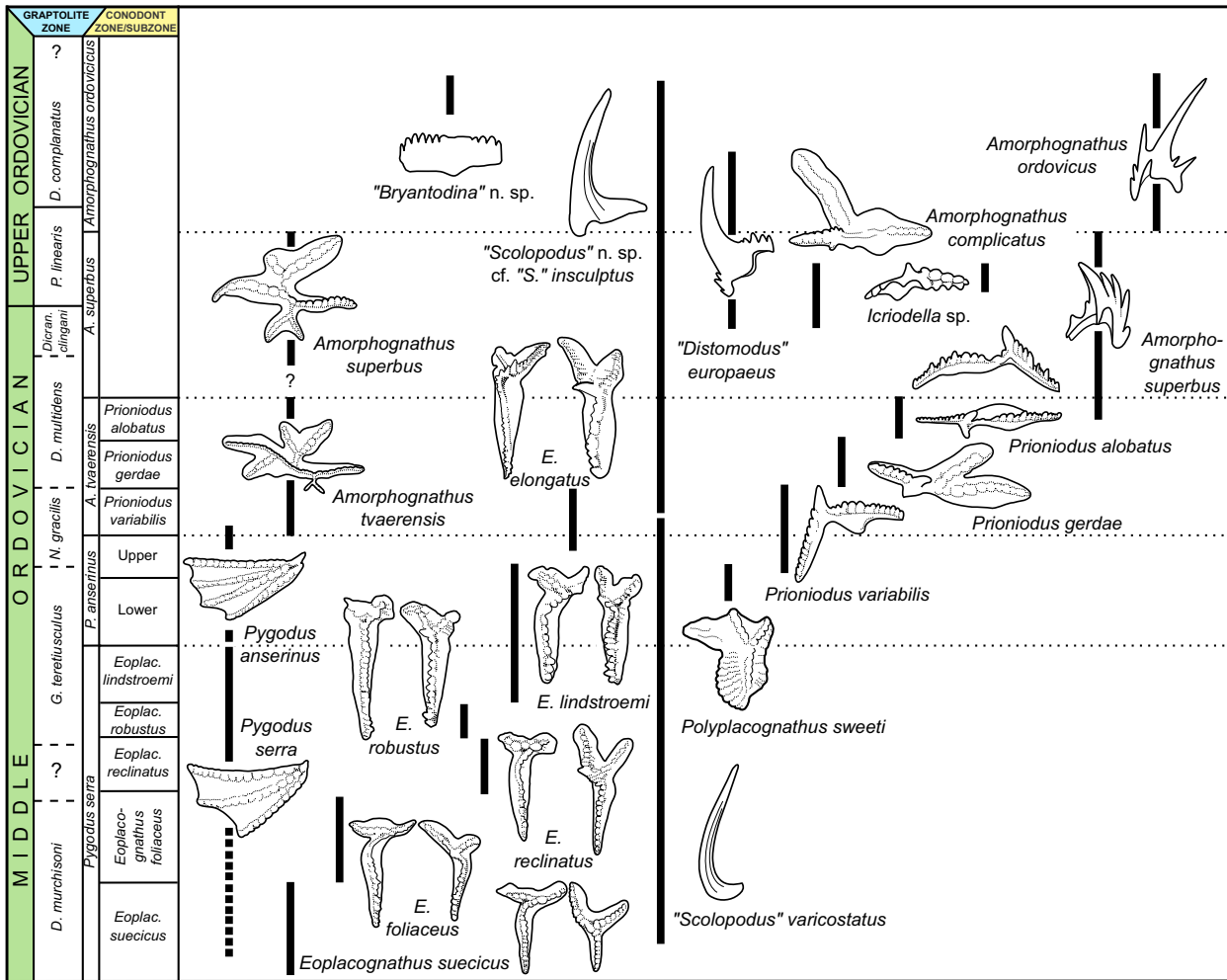


Fig. 5. The Middle and Upper Ordovician (upper Darriwilian–Hirnantian) conodont zone succession introduced by Bergström (1971) based on sections in Sweden. Also shown are ranges of key taxa. Figure slightly modified from Bergström (1971, figs 4–5). Current names of some of the taxa illustrated are as follows: ‘*Bryantodina*’ n. sp. = *Ozarkodina hassi*; ‘*Distomodus*’ *europaeus* = *Hamarodus brevirameus*; ‘*Scolopodus*’ n. sp. cf. ‘*S.*’ *insculptus* = *Protopanderodus liripipus*; ‘*Scolopodus*’ *varicostatus* = *Protopanderodus varicostatus*; *Prioniodus alobatus* = *Baltoniodus alobatus*; *Prioniodus gerdae* = *Baltoniodus gerdae*; *Prioniodus variabilis* = *Baltoniodus variabilis*; *Polyplacognathus sweeti* = *Cahabagnathus sweeti*. Also, the base of the Upper Ordovician is now at the base of the *Nemagraptus gracilis* Zone. The former *Diplograptus multidentis* Zone and the *Glyptograptus teretiusculus* Zone are now referred to as the *Climacograptus bicornis* Zone and the *Dicellograptus vagus* Zone, respectively.

Midcontinent faunas although they also contain Chinese–Siberian taxa. Unfortunately, the absence of regionally useful index-species makes it currently impossible to classify these faunas in terms of North American Midcontinent or Baltoscandic conodont zones.

Also the Lower Ordovician conodont faunas from the Australian Platform have their own provincial character (e.g. Druce & Jones 1968, 1971; McTavish 1973; Cooper 1981; Watson 1988). They show some similarity to North American Midcontinent faunas but they also contain some species that are best known from Baltoscandia. A classification into named conodont zones that can be used regionally in Australia has not yet been established. For a now

slightly outdated but still informative zone summary, see Young & Laurie (1996).

*Argentina.* – A very large amount of conodont work has been carried out during the past 20 years in the magnificent Ordovician sections in the Pre-cordillera of western Argentina, which is the only extensive region of calcareous Ordovician rocks in South America. In his pioneer monographic work on Floian to Dapingian faunas in the San Juan Limestone, Serpagli (1974) recognized five lettered local assemblage zones containing mixture of taxa of Baltoscandic and North American affinities. Subsequent work by several investigators, including among others, Mario Hünicken, Guillermo Albanesi and his



BRIT. SERIES	PACIFIC GRAPTOLITE ZONES	ZONAL TIES	NORTH ATLANTIC CONODONT ZONES	ZONAL TIES	BALTOSCANDIC GRAPTOLITE ZONES	
ASH-GILL	<i>A. inuiti</i>		<i>Amorphognathus ordovicicus</i>		<i>D. complanatus</i>	
	<i>D. complanatus</i>	↔				
	<i>C. manitoulinensis</i>	↔				
	<i>C. pygmaeus</i>	↔				
	<i>C. spiniferus</i>	↔				
CARA-DOC	<i>O. ruedemanni</i>		<i>Amorphognathus superbus</i>		<i>Pleurograptus linearis</i>	
	<i>Corynoides americanus</i>	↔				
	<i>Diplogr. multidentis</i>	↔		<i>Amorphognathus tvaerensis</i>		<i>Dicr. clingani</i>
	<i>Nemagraptus gracilis</i>	↔				
LLAN-DEILO	<i>G. cf. teretiusculus</i>	↔	<i>Pygodus anserinus</i>		<i>Dipl. multidentis</i>	
	<i>Nemagraptus gracilis</i>	↔				
LLAN-VIRN	<i>Paragl. tentaculatus</i>	↔	<i>Pygodus serra</i> <i>Eopl. suecicus</i>		<i>Nemagraptus gracilis</i>	
	<i>I. caduceus</i>	↔			<i>Glypt. teretiusculus</i>	
	<i>Did. bifidus</i>	↔			<i>Did. murchisoni</i>	
ARENIG	<i>Did. protobifidus</i>	↔	<i>Eopl.? variabilis</i> <i>M. flabellum parva</i> <i>Paroistodus originalis</i> <i>Prioniodus navis</i> <i>Prioniodus triangularis</i>		<i>Did. "bifidus"</i>	
	<i>T. fruticosus (3 + 4 br)</i>	↔			<i>Did. hirundo</i>	
	<i>T. fruticosus (4 br)</i>	↔		<i>Oepikodus evae</i>		<i>Ph. angustifolius elongatus</i>
	<i>Tetr. approximatus</i>	↔				<i>D. extensus</i>
	<i>Clonograptus</i>	↔		<i>Prioniodus elegans</i>		
	<i>Anisograptus</i>	↔				<i>Did. balticus</i>
TREMA-DOC			<i>Paroistodus proteus</i>		<i>Tetragraptus approximatus</i>	
					<i>Tetr. phyllograptoides</i>	
			<i>Drepanoistodus deltifer</i>		<i>Dictyonema, etc.</i>	
				<i>Cordylodus intermedius</i>		

Fig. 6. Zonal ties between Baltoscandic conodont zones and graptolite zones as known in the mid-1980s. After Bergström (1986, fig. 5).

students, Oliver Lehnert, and Susana Heredia, has led to the establishment of a refined Tremadocian through Sandbian conodont zone biostratigraphy (Fig. 7). For useful summaries of the current Lower and Middle Ordovician conodont biostratigraphy with data on its correlation with the graptolite zone succession, see, for instance, Albanesi & Ortega (2002), Serra *et al.* (2015), Feltes *et al.* (2016) and

Voldman *et al.* (2016). Although the faunas tend to be dominated by Baltoscandian taxa, there are also species best known from North America which provide useful links between provincial zone classifications.

Canada. – During the past 50 years, conodont biostratigraphy has been applied to numerous

Fig. 7. Comparison between conodont zone classifications of the Ordovician System in six regions. Note the conspicuous difference between some of these zone classifications. A.: *Amorphognathus*; Ac.: *Acanthodina*; Acanth.: *Acanthocordylodus*; Aph.: *Aphelognathus*; B.: *Baltoniodus*; Be: *Belodina*; C.: *Cahabagnathus*; Card.: *Cardiodella*; Ch.: *Chosonodina*; Cl.: *Colaptoconus*; Col.: *Coleodus*; Cor.: *Cordylodus*; Cu.: *Culumbodina*; E.: *Eoplacognathus*; E. protoram.: *Eoplacognathus protoramodus*; Er.: *Erismodus*; F.: *Fahraeusodus*; F. mar.: *Fahraeusodus marathonensis*; H.: *Histiodella*; I.: *Iapetognathus*; Ju.: *Jumudontus*; L.: *Lenodus*; M.: *Microzarkodina*; O.: *Oepikodus*; O. com.: *Oepikodus communis*; Ois.: *Oistodus*; Ois. multicorr.: *Oistodus multicorugatus*; Ou.: *Oulodus*; Oz.: *Ozarkodina*; P.: *Pygodus*; Pa.: *Paraserratognathus*; Pa. paltodifor.: *Paraserratognathus paltodiformis*; Pal.: *Paltodus*; Par.: *Paroistodus*; Pe.: *Periodon*; Phr.: *Phragmodus*; Pl.: *Plectodina*; Pr.: *Prioniodus*; Pt.: *Ptiloconus*; R.: *Reutterodus*; Ro.: *Rossodus*; Sc.: *Scalpellodus*; Serr.: *Serratognathus*; Sp.: *Spathognathodus*; T.: *Tripodus*; Tan.: *Tangshanodus*; Yangtz.: *Yangtzeplacognathus*; Yaoox.: *Yaooxianognathus*. Subzones: an.: *anitae* (*Pygodus anitae*); com.: *communis* (*Oepikodus communis*); fo.=foliac.: *foliaceus* (*Eoplacognathus foliaceus*); glad.: *gladysae* (*Periodon gladysae*); horr.: *horridus* (*Paroistodus horridus*); in.: *inaequalis* (*Amorphognathus inaequalis*); ki.: *kielcensis* (*Sagittodontina kielcensis*); li.=linds.: *lindstroemi* (*Eoplacognathus lindstroemi*); ma.: *magnus* (*Polonodus magnus*); re.=reclin.: *reclinatus* (*Eoplacognathus reclinatus*); ro.=robust.: *robustus* (*Eoplacognathus robustus*); swe.: *sweeti* (*Tropodus sweeti*).

Ordovician successions across Canada and conodonts have served as the major fossil group for the dating and correlation of carbonate stratigraphical units. Only a very small selection of the numerous publications by, among others, Chris Barnes, Godfrey Nowlan, Sandy McCracken and S. Zhang can be mentioned here.

Investigations of the Lower and Middle Ordovician successions on western Newfoundland have been of particular global significance. The GSSP of the base of the Ordovician, which is located at Green Point on western Newfoundland, has been the subject of much study. The most recent paper is Miller *et al.* (2014), who presented a detailed conodont zonation across the systemic boundary. The conodont faunas of the Tremadocian and Floian St. George Group, one of the finest carbonate successions of this interval in the world, was monographed by Ji & Barnes (1994), who introduced a detailed zone succession based on taxa of North American Midcontinent affinity. On the other hand, the quite different conodont faunas of the largely coeval Cow Head Group, which was deposited in deeper water, were classified using the Baltoscandic conodont zone succession (Pohler *et al.* 1987; Stouge & Bagnoli 1988; Pohler 1994; Johnston & Barnes 1999). The conodonts of the Darriwilian Table Head Group were monographed by Stouge (1984), who subdivided the succession into both assemblage and phylzones and described several key index-species. Two of these zones, the *Histiodella holodentata* Zone and the *Histiodella kristinae* Zone, have turned out to be recognizable in many parts of the world and are useful for long-distance correlations. As a whole, the Table Head conodont fauna is more similar to those of southern USA and Argentina than to equivalent Baltoscandian faunas.

The faunas of the corresponding Ordovician interval in British Columbia, western Canada (Pyle & Barnes 2001, 2002), are dominated by Midcontinent species but some Baltoscandian taxa are also present. Pyle & Barnes (2002) subdivided the Tremadocian–Darriwilian interval into eight assemblage

zones, the Darriwilian zone succession being similar to that used elsewhere in the Midcontinent.

Post-Darriwilian conodont faunas are in Canada best known from southern Ontario and the Hudson Bay region. The conodont faunal successions on Bruce Peninsula and Manitoulin Island have been discussed by several authors (e.g. Zhang *et al.* 2011). The Katian sequence of zones, which is in need of some reassessment, is mainly based on Midcontinent taxa. Of particular interest in this region is the presence of a conodont-producing Hirnantian succession in which the *Ozarkodina hassi* Zone is well developed in the Manitoulin Formation on Bruce Peninsula (Bergström *et al.* 2011). As is the case in the Midcontinent of the United States, uppermost Ordovician strata are rarely found on the Canadian craton although they are well known from Anticosti Island in Quebec, where their conodonts have been investigated by, among others, McCracken & Barnes (1981). A significant amount of work on the Ordovician conodont biostratigraphy of the Hudson Bay region and the Canadian Arctic has been carried out in recent years (e.g. Nowlan 1985; Zhang & Barnes 2007). Also the Ordovician conodont faunas of Greenland (e.g. Smith *et al.* 1989; Armstrong 1990; Smith 1991) and Svalbard (e.g. Lehnert *et al.* 2013) have been subjected to recent investigations.

USA. – The Cambrian–Ordovician boundary interval has been investigated in great detail in the Ibex area in western Utah (e.g. Miller *et al.* 2003, 2012, 2014). Based on very extensive collections, three *Cordylodus* zones have been identified in the uppermost Cambrian, and three zones, including the basalmost Ordovician *Iapetognathus* Zone, have been recognized in the lowermost Tremadocian (Fig. 7). The Ibex area has some of the finest sections across the Cambrian–Ordovician boundary in the world but its diverse conodont faunas are dominated by taxa characteristic of the tropical zone which are difficult to use for correlation with higher latitude faunas.

In an extensive study of Floian, Dapingian and Darriwilian conodont faunas from the Ibex area,

STAGE	CONODONT ZONES AND SUBZONES						
	BALTOSCANDIA	N. AMERICA	SIBERIA	S. CHINA	N. CHINA	ARGENTINE PRECORDILLERA	
HIR.	<i>Oz. hassi</i>	<i>Oz. hassi</i>	<i>Oz. hassi</i>	<i>Oz. hassi</i>			
KATIAN	<i>Amorphognathus ordovicicus</i>	<i>Aph. shatzeri</i>	<i>Aphelognathus pyramidalis</i>	<i>Aph. pyramidalis</i>	?		
		<i>Aph. divergens</i>					
		<i>Aph. grandis</i>					
	<i>Amorphognathus superbus</i>	<i>Ou. robustus</i>	<i>Ac. nobilis</i>	<i>Yaox. yaoxianensis</i>		<i>Yaox. yaoxianensis</i>	
		<i>Ou. velicuspis</i>		<i>Yaox. neimengguensis</i>		<i>Yaox. neimengguensis</i>	
SANDBIAN	<i>Amorphognathus tvaerensis</i>	<i>Be. confluens</i>	"Sp." <i>dolboricus</i>	<i>Be. confluens</i>	<i>Amorphognathus superbus</i>		
		<i>Pl. tenuis</i>	<i>Acanth. festus</i>	<i>Be. confluens</i>			
		<i>Phr. undatus</i>	<i>Cu. mangazeica</i>				
		<i>Be. compressa</i>		<i>Phr. undatus</i>		<i>Amorphognathus tvaerensis</i>	
		<i>Er. quadridactylus</i>		<i>Be. compressa</i>			<i>Er. quadridactylus</i>
DARRIWILIAN	<i>P. anserinus</i>	<i>Pl. aculeata</i>	<i>Phr. inflexus</i>	<i>B. alobatus</i>	<i>P. anserinus</i>		
		<i>C. sweeti</i>	<i>Phr. polonicus</i>	<i>E. elongatus</i>			
		<i>C. friendsvillensis</i>		<i>E. jianyeensis</i>		<i>Pl. aculeata</i>	
		<i>Phr. polonicus</i>	<i>Pr. variabilis</i>	<i>P. anserinus</i>			
		<i>H. holodentata</i>	<i>P. serra</i>	<i>P. serra</i>		<i>P. anserinus</i>	
DAPINGIAN	<i>B. norlandicus</i>	<i>H. sinuosa</i>	<i>Pt. anomalis</i>	<i>E. protoram.</i>	<i>E. suecicus</i>		
		<i>H. altifrons</i>	<i>Phr. flexuosus</i>	<i>E. foliaceus</i>			
		<i>M. flabellum - T. laevis</i>	<i>Phr. polonicus</i>	<i>P. serra</i>		<i>P. serra</i>	
		<i>O. evae</i>	<i>Scolopodus warandensis - Glyptoconus sp.</i>			<i>E. suecicus</i>	<i>E. suecicus</i>
			<i>Ju. gananda - R. andinus</i>			<i>Card. lyrata - Polyplacognathus angarensis</i>	<i>H. holodentata</i>
FLOJIAN	<i>Pr. elegans</i>	<i>O. evae</i>	<i>H. angulata</i>	<i>L. variabilis</i>	<i>Yangtz. crassus</i>		
		<i>Pr. proteus</i>	<i>Par. originalis</i>	<i>A. antivariabilis</i>			
		<i>Pal. deltifer</i>	<i>B. aff. B. navis</i>	<i>B. aff. B. navis</i>		<i>L. variabilis</i>	
TREM.	<i>Cor. angulatus</i>	<i>Par. proteus</i>	<i>H. angulata</i>	<i>B. navis</i>	<i>Pal. deltifer</i>		
		<i>Pal. deltifer</i>	<i>Scolopodus warandensis - Glyptoconus sp.</i>	<i>M. parva</i>			
		<i>Cor. lindstroemi</i>	<i>Loxodus bransonii</i>	<i>B. navis</i>		<i>T. laevis</i>	
				<i>O. intermedius</i>			
				<i>O. evae</i>			
				<i>Pa. obesus</i>			
				<i>Pa. paltodifor.</i>	<i>Pr. elegans</i>		
				<i>Serr. extensus</i>	<i>com. swe.</i>		
				<i>Serr. bilobatus</i>	<i>Par. proteus</i>		
				<i>Sc. tersus</i>			
				<i>Cl. quadruplicatus</i>	<i>Pal. deltifer</i>		
				<i>Ch. herfurthi</i>			
				<i>Ro. manitouensis</i>			
				<i>Cor. angulatus</i>			
				<i>I. jilinensis</i>			
				<i>Cor. lindstroemi</i>			

Ethington & Clark (1981) subdivided the succession into 12 intervals named for characteristic species. Younger Ordovician strata in the Great Basin were investigated by Harris *et al.* (1979). Because of the preliminary nature of this regional study, only a few conodont zones were recognized, most of which are

from the Baltoscandic zone succession. The thick Katian–Hirnantian carbonate succession in the Great Basin was investigated by Sweet (1979, 1995, 2000) and Sweet *et al.* (2005) using graphic correlation and no named conodont zones were recognized.

One of the finest and best exposed Ordovician successions in North America is in the Arbuckle Mountains in Oklahoma. Its Dapingian and Darriwilian conodont faunas have been described by, among others, Bauer (1987, 2010), who in the interval of the Joins–Oil Creek formations distinguished a series of *Histiodela* zones similar to those described by Stouge (1984) from the Table Head Group of Newfoundland. The faunas are dominated by Midcontinent taxa and have little in common with the Baltoscandic faunas. The faunas of the overlying McLish, Tulip Creek and Bromide formations also include mainly Midcontinent taxa (cf. Amsden & Sweet 1983; Bauer 1987). The former authors did not use named conodont zones to subdivide the succession. However, as has recently been shown by Wang *et al.* (2013, figs. 15–16), based on the recorded species ranges it is possible to interpret the McLish–Bromide succession in terms of North American and Baltoscandic conodont zones.

*China.* – Conodonts have been studied in the widespread Ordovician deposits in China since at least 1980 and more than 55 papers (Wang & Wang 2013), mostly written in Chinese and published in Chinese journals, record these fossils from a very large number of localities. Prominent early students of Chinese conodonts include An (1981, 1987), An *et al.* (1983, 1985), An & Ding (1985), and Ni & Li (1987). The many later contributions include, among others, Wang (1993), Wang & Zhou (1998), Zhao *et al.* (2000), Zhang (1998b), Wang *et al.* (1996, 2013), Zhan & Jin (2007) and Zhen *et al.* (2009, 2011). As summarized by Wang *et al.* (1996), the very conspicuous provincial differentiation in the Chinese Ordovician conodont faunas has made it necessary to introduce radically different zone classifications for different parts of the country. Whereas the 28 conodont zones recognized in the South China Province (Fig. 7) are, with a couple of exceptions, basically the same as those in Baltoscandia, the zones recorded in the North China Province are mostly vastly different although they contain a couple of North American index-species. Research since the early 1990s has resulted in some modifications of the zone successions. For a modern review of zones recognized in South China, see Zhan & Jin (2007, p. 91–94), and for a recent discussion, with many references, of Middle and Upper Ordovician Chinese conodont biostratigraphy, see Wang *et al.* (2013). Recently, Zhen *et al.* (2016) revised the Ordovician conodont biostratigraphy of the extensive carbonate successions on the North China platform (cf. Fig. 7) that contain a mixture of endemic,

North American Midcontinent, and more or less pandemic species.

*South-East Asia.* – Recent work in the relatively thick Ordovician carbonate successions in Thailand and Malaysia by Agematsu *et al.* (2008a,b) has led to the discovery of notable conodont faunas. Whereas those of Tremadocian and slightly younger age are of North American type, the Sandbian–Katian faunas are dominated by taxa best known from Baltoscandia.

## Concluding remarks

As shown by, for instance, Sweet (1988), conodont species diversity is much higher in the Ordovician than in any other system. Many of these species combine a short vertical range with abundant occurrence and serve as excellent index fossils. However, the fact that the continental plates with their shallow-water depositional environments occupied a variety of latitudinal positions with different water temperatures and other ecologically important parameters caused a pronounced provincial differentiation of the Ordovician conodont faunas (e.g. Sweet & Bergström 1974, 1984; Bergström 1990b) and the limited geographic distribution of many biostratigraphically key species has resulted in the fact that it has been impossible to produce a globally applicable conodont zone classification and markedly different sets of zones have been defined in, for instance, the North American Midcontinent, Baltoscandia, North China and Siberia. Recent work in regions with some mixing of the provincial faunas, such as the Appalachians in eastern North America, the Precordillera of Argentina and some parts of China, has helped tie together parts of the provincial zone classifications but much more work of that type remains to be done. Also, there is a need in some areas, for instance, in the North American Midcontinent, to reassess and improve the existing zone classifications. However, as is clear from this brief review, the extensive conodont biostratigraphical work carried out during the last half-century has resulted in that Ordovician conodont biostratigraphy has reached a relatively mature state in most parts of the world.

A matter of general concern is that compared with that of the last decades of the 20<sup>th</sup> century, research on Ordovician conodont biostratigraphy has slowed down in recent years in, for instance North America and Baltoscandia. Only a couple of universities in North America now offer masters or PhD programmes in conodont research supervised by a



specialist. Taxonomic work is no longer very attractive as student thesis projects. This is alarming in view of the fact that a solid taxonomic background is essential for high-quality biostratigraphical work. The disappearance of conodont specialists is not unique but is shared with quite a few other fossil groups. It may well be that the 'golden age' of Ordovician conodont biostratigraphical research is not far from its end. Let us hope that in the future, this pessimistic forecast will prove to be in error.

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## References

- Abaimova, G.P. 1971: New Early Ordovician conodonts from the southeastern part of the Siberian Platform. *Palaeontological Journal* 1971, 486–493.
- Agematsu, S., Sashida, K., Salyapongse, S. & Sardud, A. 2008a: Early Ordovician conodonts from Tarutao Island, Southern Peninsular Thailand. *Palaeontology* 51, 1435–1453.
- Agematsu, S., Sashida, K. & Ibrahim, A.B. 2008b: Biostratigraphy and Paleobiogeography of Middle and Late Ordovician conodonts from the Langkawi Islands, northwestern Peninsular Malaysia. *Journal of Paleontology* 82, 957–973.
- Albanesi, G.L. & Ortega, G. 2002: Advances on conodont-graptolite biostratigraphy of the Ordovician System of Argentina. *INSUGEO Serie Correlación Geológica* 16, 145–166.
- Álvarez, J.J., Ferretti, A., González-Gómez, C., Serpagli, E., Tortello, M.F., Vecoli, M. & Vizcaino, D. 2007: A review of the Late Cambrian (Furongian) palaeogeography in the western Mediterranean region, NW Gondwana. *Earth-Science Reviews* 85, 47–81.
- Amsden, T.W. & Sweet, W.C. 1983: Upper Bromide Formation and Viola Group (Middle and Upper Ordovician) in eastern Oklahoma. *Oklahoma Geological Survey Bulletin* 132, 1–76.
- An, T. 1981: Recent progress in Cambrian and Ordovician conodont biostratigraphy in China. *Geological Society of America Special Paper* 187, 209–226.
- An, T. 1987: [Early Paleozoic conodonts of South China], 238 pp. Beijing University Press, Beijing (in Chinese).
- An, T. & Ding, L.S. 1985: [Ordovician conodont biostratigraphy in Hexian, Anhui Province]. *Geological Review* 13, 1–12 (in Chinese).
- An, T.X., Zhang, F., Xiang, W.D., Zhang, Y.Q., Xi, W.H., Zhang, H.J., Jiang, D.R., Yang, C.S., Lin, L.D., Cui, Z.T. & Yang, X.C. 1983: The conodonts of North China and the adjacent regions, 223 pp. Science Press, Beijing (in Chinese with English abstract).
- An, T.X., Zhang, A.T. & Xu, J.M. 1985: Ordovician conodonts from Yaoxian and Fuping, Shaanxi Province, and their stratigraphic significance. *Acta Geologica Sinica* 59, 97–108 (in Chinese with English abstract).
- Armstrong, H.A. 1990: Conodonts from the Upper Ordovician–Lower Silurian carbonate platform of north Greenland. *Bulletin Grønlands Geologiske Undersøgelse* 159, 1–151.
- Armstrong, H.A. 1997: Conodonts from the Ordovician Shinnel Formation, Southern Uplands, Scotland. *Palaeontology* 40, 763–797.
- Bagnoli, G. & Stouge, S. 1997: Lower Ordovician (Billingenian–Kunda) conodont zonation and provinces based on sections from Horns Udde, north Öland, Sweden. *Bollettino della Società Paleontologica Italiana* 35, 109–163.
- Balini, M., Ferretti, A., Finney, S. & Monechi, S. this issue: The contribution of fossils to Chronostratigraphy, 150 years after Albert Oppel. *Lethaia*.
- Bauer, J.A. 1987: Conodonts and conodont biostratigraphy of the McLish and Tulip Creek formations (Middle Ordovician) of south-central Oklahoma. *Bulletin of the Oklahoma Geological Survey* 141, 1–58.
- Bauer, J.A. 2010: Conodonts and conodont biostratigraphy of the Joins and Oil Creek formations, Arbuckle Mountains, south-central Oklahoma. *Bulletin of the Oklahoma Geological Survey* 150, 1–44.
- Bergström, S.M. 1971: Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America. *Geological Society of America Memoir* 127, 83–157.
- Bergström, S.M. 1973: Biostratigraphy and facies relations in the lowermost Middle Ordovician of easternmost Tennessee. *American Journal of Science* 273-A, 261–293.
- Bergström, S.M. 1978: Middle and Upper Ordovician conodont and graptolite biostratigraphy of the Marathon, Texas graptolite zone reference standard. *Palaeontology* 21, 723–758.
- Bergström, S.M. 1986: Biostratigraphic integration of Ordovician graptolite and conodont zones—a regional review. In Hughes, C.P. & Rickards, R.B. (eds) *Palaeoecology and Biostratigraphy of Graptolites*. *Geological Society of London Special Publication* 30, 61–78.
- Bergström, S.M. 1988: On Pander's conodonts. Distribution and significance of the *Prioniodus elegans* fauna in Baltoscandia. *Senckenbergiana Lethaea* 69, 217–251.
- Bergström, S.M. 1990a: Biostratigraphic and biogeographic significance of Middle and Upper Ordovician conodonts in the Girvan succession, south-west Scotland. *Courier Forschungsinstitut Senckenberg* 118, 1–43.
- Bergström, S.M. 1990b: Relations between conodont provincialism and the changing palaeogeography during the Early Palaeozoic. In McKerrow, W.S. & Scotese, C.R. (eds) *Palaeozoic Palaeogeography and Biogeography*. *Geological Society of London Memoir* 12, 105–121.
- Bergström, S.M. 2007: The Ordovician conodont biostratigraphy of the Siljan region, south-central Sweden: a brief review of an international reference standard. *Sveriges Geologiska Undersökning (Geological Survey of Sweden), Rapporter och Meddelanden* 128, 26–41, 63–78.
- Bergström, S.M. & Carnes, J.B. 1976: Conodont biostratigraphy and paleoecology of the Holston Limestone (Middle Ordovician) and associated strata in eastern Tennessee. *Geological Association of Canada Special Paper* 15, 27–57.
- Bergström, S.M. & Ferretti, A. 2015: Conodonts in the Upper Ordovician Keisley Limestone of northern England: taxonomy, biostratigraphical significance and biogeographical relationships. *Papers in Palaeontology* 93, 1–32.
- Bergström, S.M. & Löfgren, A. 2009: The base of the global Dapingian Stage (Ordovician) in Baltoscandia: conodonts, graptolites and unconformities. *Earth and Environmental Transactions of the Royal Society of Edinburgh* 99, 189–212.
- Bergström, S.M. & Massa, D. 1992: Stratigraphic and biostratigraphic significance of Upper Ordovician conodonts from northwestern Libya. In Salem, M.J., Hammuda, O.S. & Elia-goubi, B.A. (eds): *The Geology of Libya, Vol IV*, 1323–1342. Elsevier Science Publishers, Amsterdam.
- Bergström, S.M. & Sweet, W.C. 1966: Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana. *Bulletins of American Paleontology* 50, 269–441.
- Bergström, S.M., Riva, J. & Kay, M. 1974: Significance of conodonts, graptolites, and shelly faunas from the Ordovician of western and central Newfoundland. *Canadian Journal of Earth Sciences* 11, 1625–1660.
- Bergström, S.M., Chen, X., Gutiérrez-Marco, J.C. & Dronov, A. 2009: The new chronostratigraphic classification of the Ordovician System and its relations to major regional series and stages and to  $\delta^{13}\text{C}$  chemostratigraphy. *Lethaia* 42, 97–107.



- Bergström, S.M., Kleffner, M., Schmitz, B. & Cramer, B.D. 2011: Revision of the position of the Ordovician-Silurian boundary in southern Ontario: regional chronostratigraphical implications of  $\delta^{13}\text{C}$  chemostratigraphy of the Manitoulin Formation and associated strata. *Canadian Journal of Earth Sciences* 48, 1447–1470.
- Branson, E.B. & Mehl, M.G. 1933: Conodont studies. *University of Missouri Studies* 8, 1–349.
- Branson, E.B., Mehl, M.G. & Branson, C.C. 1951: Richmond conodonts of Kentucky and Indiana. *Journal of Paleontology* 25, 1–17.
- Burgett, C., Stait, B. & Laurie, J. 1983: Trilobites and microfossils from the Middle Ordovician of Surprise Bay, southern Tasmania, Australia. *Memoirs of the Association of Australasian Palaeontologists* 1, 177–193.
- Cooper, B.J. 1981: Early Ordovician conodonts from the Horn Valley Siltstone, central Australia. *Palaeontology* 24, 147–183.
- Cullison, J.S. 1938: Dutchtown fauna of southeastern Missouri. *Journal of Paleontology* 12, 219–228.
- Del Moral, B. & Sarmiento, G.N. 2008: Conodonts del Katiense (Ordovícico Superior) del sector meridional de la Zona Centroibérica (España). *Revista de Micropaleontología* 40, 169–245.
- Druce, E.C. & Jones, P.J. 1968: Stratigraphical significance of conodonts in the Upper Cambrian and Lower Ordovician sequence of the Boulia region, Western Queensland. *Australian Journal of Science* 31, 1–88.
- Druce, E.C. & Jones, P.J. 1971: Cambro-Ordovician conodonts from the Burke River Structural Belt, Queensland. *Bureau of Mineral Resources, Australia Bulletin* 110, 1–158.
- Dubinina, S.V. 2000: [Conodonts and zonal stratigraphy of the Cambrian-Ordovician boundary deposits], 237 pp. Moscow 'Nauka' (in Russian).
- Dumoulin, J.A., Harris, A.G., Gagiev, M., Bradley, D.C. & Repetski, J.E. 2002: Lithostratigraphic, conodont, and other faunal links between lower Paleozoic strata in northern and central Alaska and northeastern Russia. In Miller, E.L., Grantz, A. & Klempner, S.L. (eds) *Tectonic Evolution of the Bering Shelf–Chukchi Sea–Arctic Margin and Adjacent Landmasses: Boulder, Colorado. Geological Society of America Special Paper* 360, 291–312.
- Dzik, J. 1976: Remarks on the evolution of Ordovician conodonts. *Acta Palaeontologica Polonica* 21, 395–445.
- Dzik, J. 1990: Conodont evolution in high latitudes of the Ordovician. *Courier der Forschungsinstitut Senckenberg* 117, 1–28.
- Dzik, J. 1994: Conodonts of the Mójca Limestone. In Dzik, J., Olemska, E., Pisera, A. *Ordovician Carbonate Platform Ecosystem of the Holy Cross Mountains. Palaeontologica Polonica* 53, 43–128.
- Ethington, R.L. & Clark, D.L. 1971: Lower Ordovician conodonts in North America. *Geological Society of America Memoir* 127, 63–82.
- Ethington, R.L. & Clark, D.L. 1981: Lower and Middle Ordovician conodonts from the Ibex area, western Millard County, Utah. *Brigham Young University Geology Studies* 28, 1–160.
- Feltes, N.A., Albanesi, G.L. & Bergström, S.M. 2016: Conodont biostratigraphy and global correlation of the middle Darriwilian-lower Sandbian (Ordovician) Las Aguaditas Formation, Precordillera de San Juan, Argentina. *Andean Geology* 43, 60–85.
- Ferretti, A. & Barnes, C.R. 1997: Upper Ordovician conodonts from the Kalkbank of Thuringia (Germany). *Palaeontology* 40, 15–42.
- Ferretti, A. & Schönlaub, H.P. 2001: New conodont faunas from the Late Ordovician of the Central Carnic Alps, Austria. *Bollettino della Società Paleontologica Italiana* 40, 3–15.
- Ferretti, A. & Serpagli, E. 1991: First record of Ordovician conodonts from Southwestern Sardinia. *Rivista Italiana di Paleontologia e Stratigrafia* 97, 27–34.
- Ferretti, A. & Serpagli, E. 1999: Late Ordovician conodont faunas from southern Sardinia, Italy: biostratigraphic and paleogeographic implications. *Bollettino della Società Paleontologica Italiana* 37, 215–236.
- Ferretti, A., Bergström, S.M. & Barnes, C.R. 2014a: Katian (Upper Ordovician) conodonts from Wales. *Palaeontology* 57, 801–831.
- Ferretti, A., Bergström, S.M. & Sevastopulo, G.D. 2014b: Katian conodonts from the Portrane Limestone: the first Ordovician conodont fauna described from Ireland. *Bollettino della Società Paleontologica Italiana* 53, 105–119.
- Ferretti, A., Messori, A. & Bergström, S.M. 2014c: Composition and significance of the Katian (Upper Ordovician) conodont fauna of the Vaux Limestone ('Calcaire des Vaux') in Normandy, France. *Estonian Journal of Earth Sciences* 63, 214–219.
- Furnish, W.M. 1938: Conodonts from the Prairie du Chien (Lower Ordovician) beds of the Upper Mississippi Valley. *Journal of Paleontology* 12, 318–340.
- Graves, R.W. & Ellison, S. 1941: Ordovician conodonts of the Marathon Basin, Texas. *University Missouri School of Mines and Metallurgy Bulletin Technical Series* 14, 1–16.
- Hadding, A. 1913: Undre Dichellograptusskiffern i Skåne jämte några därmed ekvivalenta bildningar. *Lunds Universitets Årsskrift N.F.2*, 9, 1–90.
- Harris, A.G., Bergström, S.M., Ethington, R.L. & Ross, R.J. Jr 1979: Aspects of Middle and Upper Ordovician conodont biostratigraphy of carbonate facies in Nevada and southern California and comparison with some Appalachian successions. *Brigham Young University Geology Studies* 26, 7–33.
- Hinde, G.J. 1879: On conodonts from the Chazy and Cincinnati Group of the Cambro-Silurian, and from the Hamilton and Genesee Shale divisions of the Devonian, in Canada and the United States. *Quarterly Journal of the Geological Society of London* 35, 351–369.
- Holm, G. 1890: Gotlands graptoliter. *Bihang till K. Svenska Vetenskapsakademiens Handlingar* 16, 1–34.
- Ji, Z. & Barnes, C.R. 1994: Lower Ordovician conodonts of the St. George Group, Port-au-Port Peninsula, western Newfoundland, Canada. *Palaeontographica Canadiana* 11, 1–149.
- Johnston, D.I. & Barnes, C.R. 1999: Early and Middle Ordovician (Arenig) conodonts from the St. Pauls Inlet and Martin Point, Cow Head Group, western Newfoundland, Canada. 1. Biostratigraphy and Paleocology. *Geologica et Palaeontologica* 33, 1–70.
- Kanygin, A.V., Timokhin, A.V., Sennikov, N.V., Yadrenkina, A.G., Gonta, T.V., Sychev, O.V., Obut, O.T. & Kipriynova, T.P. 2006: Ordovician sequence of the key Kulyumbe section (Siberian Platform). *Field Excursion Guidebook, International Symposium and Field Trip (IGCP 503 Project)*. Novosibirsk, Aug. 5–16, 2006. 91 pp. Academic Publishing House 'GEO', Novosibirsk.
- Knüpfner, J. 1967: Zur Fauna und Biostratigraphie des Ordoviziums (Gräfenthaler Schichten) in Thüringen. *Freiberger Forschungshefte C220*, 1–119.
- Lapworth, C. 1878: The Moffat Series. *Quarterly Journal of the Geological Society of London* 34, 240–346.
- Lehnert, O., Stouge, S. & Brandl, P.A. 2013: Conodont biostratigraphy in the Early to Middle Ordovician strata of the Oslo-breen Group in Ny Friesland, Svalbard. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften* 164, 149–172.
- Lehnert, O., Nowak, H., Sarmiento, G.N., Gutiérrez-Marco, J.C., Akodad, M. & Servais, T. 2016: Conodonts from the Lower Ordovician of Morocco – Contributions to age and faunal diversity of the Fezouata Lagerstätte and peri-Gondwana biogeography. *Palaeogeography, Palaeoclimatology, Palaeoecology* 460, 50–61.
- Lindström, M. 1955: Conodonts from the lowermost Ordovician strata in south-central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 76, 517–604.
- Lindström, M. 1971: Lower Ordovician conodonts of Europe. *Geological Society of America Memoir* 127, 21–61.
- Lindström, M. & Pelhate, A. 1971: Présence de conodontes dans les calcaires de Rosan (Ordovicien moyen à supérieur, Massif Armoricaïn). Colloque Ordovicien–Silurien, Brest 1971. *Mémoire du Bureau de Recherches Géologiques et Minières* 73, 89–91.

- Löfgren, A. 1978: Arenigian and Llanvirnian conodonts from Jämtland, Sweden. *Fossils and Strata* 13, 1–129.
- Löfgren, A. 1985: Early Ordovician conodont biozonation at Finngrundet, south Bothnian Bay, Sweden. *Bulletin of the Geological Institute of the University of Uppsala, N.S.* 10, 115–128.
- Löfgren, A. 1993: Arenig conodont succession from central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 115, 193–207.
- Löfgren, A. 1994: Arenig (Lower Ordovician) conodonts and biostratigraphy in the eastern Siljan district, central Sweden. *Journal of Paleontology* 68, 1350–1368.
- Löfgren, A. 1995: The middle Lanna/Volkhov Stage (middle Arenig) of Sweden and its conodont fauna. *Geological Magazine* 132, 693–711.
- Löfgren, A. 2000: Early and Middle Ordovician conodont biostratigraphy of the Gillberga quarry, northern Öland, Sweden. *GFF* 122, 321–338.
- Löfgren, A. & Tolmacheva, T. 2008: Morphology, evolution and stratigraphic distribution in the Middle Ordovician conodont genus *Microzarkodina*. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 99, 27–48.
- Männik, P. & Viira, V. 2012: Ordovician conodont diversity in the northern Baltic. *Estonian Journal of Earth Sciences* 61, 1–14.
- McCracken, A.D. & Barnes, C.R. 1981: Conodont biostratigraphy and paleoecology of the Ellis Bay Formation, Anticosti Island, Quebec, with special reference to Late Ordovician-Early Silurian chronostratigraphy and the systemic boundary. *Geological Survey of Canada Bulletin* 329, 51–134.
- McTavish, R.A. 1973: Prioniodontacean conodonts from the Emanuel Formation (Lower Ordovician) of Western Australia. *Geologica et Palaeontologica* 7, 27–58.
- Miller, J.F., Evans, K.R., Loch, J.D., Ethington, R.L., Stitt, J.H., Holmer, L. & Popov, L.E. 2003: Stratigraphy of the Sauk III interval (Cambrian-Ordovician) in the Ibex area, western Millard County, Utah and central Texas. *Brigham Young University Geology Studies* 47, 23–118.
- Miller, J.F., Loch, J.D. & Taylor, J.F. 2012: Biostratigraphy of Cambrian and Lower Ordovician strata in the Llano Uplift, central Texas. In Derby, J.R., Fritz, R.D., Longacre, S.A., Morgan, W.A. & Sternbach, C.A. (eds) *The Geology and economic resources of the Cambrian-Ordovician Sauk Megasequence of Laurentia*. AAPG Memoir 98, 187–202.
- Miller, J.F., Repetski, J.E., Nicoll, R.S., Nowlan, G. & Ethington, R.L. 2014: The conodont *Iapetognathus* and its value for defining the base of the Ordovician System. *GFF* 136, 185–188.
- Moskalenko, T. 1973: [Conodonts of the Middle and Upper Ordovician of the Siberian Platform]. *Akademiya Nauk SSR. Sibirskoe Ordlinie, Trudy Instituta Geologii i Geofiziki* 137, 1–143 (in Russian).
- Moskalenko, T.A. 1983: Conodonts and biostratigraphy in the Ordovician of the Siberian Platform. *Fossils and Strata* 15, 87–94.
- Ni, S.Z. & Li, Z.H. 1987: [The Ordovician conodonts from Yangtze Gorges area. In Wang, X.F. & Ni, S.Z. (eds) *Biostratigraphy of Yangtze Gorges area (2). Palaeozoic Era.*] *Geological Publishing House Beijing*, 102–114, 386–447 (in Chinese with English abstract).
- Nowlan, G.S. 1985: Cambrian-Ordovician conodonts from the Franklinian miogeosyncline, Canadian Arctic Islands. *Journal of Paleontology* 59, 96–122.
- Orchard, M.J. 1980: Upper Ordovician conodonts from England and Wales. *Geologica et Palaeontologica* 14, 9–44.
- Pander, C.H. 1856: *Monographie der fossilen Fische des silurischen Systems der Russisch-Baltischen Gouvernements*. 91 pp. Buchdruckerei Kaiserlichen Akademie des Wissenschaften, St. Petersburg.
- Paris, F., Pelhate, A. & Weyant, M. 1981: Conodontes ashgilliens dans la Formation de Rosan, coupe de Lostmarc'h (Finistère, Massif armoricain). Conséquences paléogéographiques. *Bulletin de la Société Géologique et Mineralogique de Bretagne* 13, 15–35.
- Pohler, S.M.L. 1994: Conodont biofacies of Lower and lower Middle Ordovician megaconglomerates, Cow Head Group, western Newfoundland. *Geological Survey of Canada Bulletin* 459, 1–73.
- Pohler, S.M.L., Barnes, C.R. & James, N.P. 1987: Reconstructing a lost faunal realm: conodonts from the Ordovician Cow Head Group, western Newfoundland. In Austin, R. (ed.): *Conodonts: Investigative Techniques and Applications*, 341–362. Ellis Horwood, Chichester.
- Pyle, L.J. & Barnes, C.R. 2001: Conodonts from the Kechika Formation and Road River Group (Lower to Upper Ordovician) of the Cassiar Terrane, northern British Columbia. *Canadian Journal of Earth Sciences* 38, 1387–1401.
- Pyle, L.J. & Barnes, C.R. 2002: *Taxonomy, Evolution, and Biostratigraphy of Conodonts from the Kechika Formation, Skoki Formation, and the Road River Group (Upper Cambrian to Lower Silurian) Northeastern British Columbia*, 227 pp. NRC Research Press, Ottawa.
- Rasmussen, J.A. 2001: Conodont biostratigraphy and taxonomy of the Lower Ordovician shelf margin deposits in the Scandinavian Caledonides. *Fossils and Strata* 48, 1–180.
- Rhodes, F.H.T. 1953: Some British lower Palaeozoic conodont faunas. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* 237, 261–334.
- Rhodes, F.H.T. 1955: The conodont fauna of the Keisley Limestone. *Quarterly Journal of the Geological Society of London* 111, 117–142.
- Sarmiento, G.N., Gutiérrez-Marco, J.C., Rodríguez-Cañero, R., Martín Algarra, A. & Navas-Parejo, P. 2011: A brief summary of Ordovician conodont faunas from the Iberian Peninsula. In Gutiérrez-Marco, J.C., Rábano, I. & García-Bellido, D. (eds) *Ordovician of the World*. Cuadernos del Museo Geominero 14, Instituto Geológico y Minero de España, 505–514.
- Savage, N.M. & Bassett, M.G. 1985: Caradoc-Ashgill conodont faunas from Wales and the Welsh Borderland. *Palaeontology* 28, 679–713.
- Sennikov, N.V., Ainsaarb, L. & Meidla, T. 2015: Hirnantian Isotope Carbon Excursion in Gorny Altai, southwestern Siberia. *Estonian Journal of Earth Sciences* 64, 225–232.
- Sergeeva, S.P. 1964: On the stratigraphic significance of the Lower Ordovician conodonts of the Leningrad region. *Leningrad University Vestnik, Serie Geologiya i Geografi* 12, 56–60 (in Russian).
- Serpagli, E. 1967: I conodonti dell'Ordoviciano Superiore (Ashgilliano) delle Alpi Carniche. *Bollettino della Società Paleontologica Italiana* 6, 30–111.
- Serpagli, E. 1974: Lower Ordovician conodonts from Precordillera Argentina (Province of San Juan). *Bollettino della Società Paleontologica Italiana* 13, 17–98.
- Serpagli, E., Ferretti, A., Vizcaíno, D. & Álvaro, J.J. 2007: A new Early Ordovician conodont genus from southern Montagne Noire, France. *Palaeontology* 50, 1447–1457.
- Serpagli, E., Ferretti, A., Nicoll, R. & Serventi, P. 2008: The conodont genus *Teridontus* (Miller, 1980) from the Early Ordovician of Montagne Noire, France. *Journal of Paleontology* 82, 612–620.
- Serra, F., Albanesi, G.L., Ortega, G. & Bergström, S.M. 2015: Biostratigraphy and palaeoecology of Middle-Late Ordovician conodont and graptolite faunas of the Las Chacritas River section, Precordillera of San Juan, Argentina. *Geological Magazine* 152, 813–829.
- Smith, J. 1907: On the occurrence of conodonts in the Arenig-Llandeilo formation of the Southern Uplands of Scotland. *Transactions of the Natural History Society, Glasgow* 7, 235–252.
- Smith, M.P. 1991: Early Ordovician conodonts of East and North Greenland. *Meddelelser om Grønland Geoscience* 26, 1–81.
- Smith, M.P., Sønderholm, M. & Tull, S. 1989: The Morris Bugt Group (Middle Ordovician-Silurian) of North Greenland and its correlatives. *Rapport Grønlands Geologiske Undersøkelse* 143, 5–20.
- Stauffer, C.R. 1935a: Conodonts of the Glenwood beds. *Bulletin of the Geological Society of America* 46, 125–168.
- Stauffer, C.R. 1935b: The conodont fauna of the Decorah Shale (Ordovician). *Journal of Paleontology* 9, 596–620.
- Stouge, S. 1984: Conodonts of the Middle Ordovician Table Head Formation, western Newfoundland. *Fossils and Strata* 16, 1–145.

- Stouge, S. & Bagnoli, G. 1988: Early Ordovician conodonts from Cow Head Peninsula, western Newfoundland. *Palaeontographia Italica* 75, 89–179.
- Stouge, S. & Bagnoli, G. 1991: Lower Ordovician (Volkhovian-Kundan) conodonts from Hagudden, northern Öland, Sweden. *Palaeontographia Italica* 77, 1–54.
- Sweet, W.C. 1979: Late Ordovician conodonts and biostratigraphy of the Western Midcontinent Province. *Brigham Young University Geology Studies* 26, 45–85.
- Sweet, W.C. 1984: Graphic correlation of upper Middle and Upper Ordovician rocks, North American Midcontinent Province, U.S.A. In Bruton, D.L. (ed.) *Aspects of the Ordovician System*. Paleontological Contributions of the University of Oslo 295, 23–35.
- Sweet, W.C. 1988: *The Conodonta. Morphology, Taxonomy, Paleocology and Evolutionary History of a long-extinct animal Phylum*, 212 pp. Oxford University Press, New York.
- Sweet, W.C. 1995: Graphic assembly of a conodont-based composite standard for the Ordovician System in North America. *Society of Sedimentary Geology Special Publication* 53, 141–150.
- Sweet, W.C. 2000: Conodonts and biostratigraphy of Upper Ordovician strata along a shelf to basin transect in central Nevada. *Journal of Paleontology* 74, 1148–1160.
- Sweet, W.C. & Bergström, S.M. 1974: Conodont biostratigraphy of the Middle and Upper Ordovician of the United States Midcontinent. In Bassett, M.G. (ed.), *The Ordovician System*. The University of Wales Press and National Museum of Wales, Cardiff, 121–151.
- Sweet, W.C. & Bergström, S.M. 1984: Conodont provinces and biofacies in the Late Ordovician. *Geological Society of America Special Paper* 196, 69–87.
- Sweet, W.C., Ethington, R.L. & Barnes, C.R. 1971: North American Middle and Upper Ordovician conodont faunas. *Geological Society of America Memoir* 127, 163–193.
- Sweet, W.C., Ethington, R.L. & Harris, A.G. 2005: A conodont-based standard reference section in central Nevada for the lower Middle Ordovician Whiterockian Series. *Bulletins of American Paleontology* 369, 35–52.
- Tjernvik, T. 1952: Om de lägsta ordoviciska lagren i Närke. *Geologiska Föreningens i Stockholm Förhandlingar* 74, 51–70.
- Tjernvik, T. 1956: On the Early Ordovician of Sweden. Stratigraphy and Fauna. *Uppsala Universitets Geological Institution Bulletin* 36, 107–254.
- Tolmacheva, T.Y. 2014: Biostratigraphy and biogeography of the Ordovician conodonts of the western part of Central-Asian Fold Belt. *Trudy VSEGEI, New Series* 356, 1–264 (in Russian).
- Tolmacheva, T.Y. & Abaimova, G.P. 2009: Late Cambrian and Early Ordovician conodonts from the Kulumbe River section, southwest Siberian Platform. *Memoires of the Association of Australasian Palaeontologists* 37, 427–451.
- Tolmacheva, T.Y., Degtyarev, K.E., Ryazantsev, A.V. & Nikitina, O.I. 2009: Conodonts from the upper Ordovician siliceous rocks of Central Kazakhstan. *Paleontological Journal* 43, 1498–1512.
- Viira, V. 1966: [Distribution of conodonts in the Lower Ordovician sequence at Sukhrumägi (Tallinn)]. *Eesti NSV Teaduste Acad. Toimetised* 15, 150–155 (in Russian with English abstract).
- Viira, V. 1974: [Conodonts from the Ordovician of the East Baltic], 142 pp. Valgus, Tallinn (in Russian).
- Viira, V. 2011: Lower and Middle Ordovician conodonts from the subsurface of SE Estonia and adjacent Russia. *Estonian Journal of Earth Sciences* 60, 1–21.
- Voldman, G.G., Albanesi, G.L., Ortega, G., Giuliano, M.E. & Monaldi, C.R. 2016: New conodont taxa and biozones from the Lower Ordovician of the Cordillera Oriental, NW Argentina. *Geological Journal*, doi: 10.1002/gj.2766.
- Wang, C.Y. (ed.) 1993: [Conodonts of The Lower Yangtze Valley—an Index to Biostratigraphy and Organic Metamorphic Maturity], 326 pp. Science Press, Beijing (in Chinese with English summary).
- Wang, C.Y. & Wang, P. 2013: *Chinese Bibliography of Conodonts (1960–2013)*, 76 pp. Privately printed, Nanjing.
- Wang, Z.H. & Zhou, T.R. 1998: Ordovician conodonts from western and southeastern Tarim and their significance. *Acta Palaeontologica Sinica* 37, 173–183.
- Wang, Z.H., Bergström, S.M. & Lane, H. 1996: Conodont provinces and biostratigraphy in Ordovician of China. *Acta Palaeontologica Sinica* 35, 26–59.
- Wang, Z.H., Bergström, S.M., Yong, Y.Z., Xu, C. & Zhang, Y.D. 2013: On the integration of Ordovician conodont and graptolite biostratigraphy: new examples from Gansu and Inner Mongolia in China. *Alcheringa* 37, 810–828.
- Watson, S.T. 1988: Ordovician conodonts from the Canning Basin (W. Australia). *Palaeontographica* 203A, 91–147.
- Webers, G.F. 1966: The Middle and Upper Ordovician conodont faunas of Minnesota. Minnesota Geological Survey Special Publication Series 4. 123 pp.
- Weyant, M., Dorè, F., Le Gall, J. & Poncet, J. 1977: Un épisode calcaire ashgillien dans l'est du Massif armoricain; incidence sur l'âge des dépôts glacio-marins fini-ordoviens. *Comptes Rendus de l'Académie des Sciences Paris* 284, 1147–1149.
- Wiman, C. 1895: Über die Graptoliten. *Bulletin of the Geological Institution of Uppsala* 2, 239–316.
- Wiman, C. 1903: Studien über des Nordbaltische Silurgebiet. 1. Olenellussandstein, Obolussandstein und Ceratopygesschiefer. *Bulletin of the Geological Institution of Uppsala* 6, 12–76.
- Young, G.C. & Laurie, J.R. 1996: *An Australian Phanerozoic Timescale*, 279 pp. Oxford University Press, Melbourne.
- Zhan, R. & Jin, J. 2007: *Ordovician-Early Silurian (Llandovery) Stratigraphy and Paleontology of the Upper Yangtze Platform, South China*, 169 pp. Science Press, Beijing.
- Zhang, J. 1998a: The Ordovician conodont genus *Pygodus*. In Szaniawski, H. (ed.) *Proceedings of the Sixth European Conodont Symposium (ECOS VI)*. *Palaeontologia Polonica* 58, 87–105.
- Zhang, J. 1998b: Conodonts from the Guniutan Formation (Llanvirnian) in Hubei and Hunan provinces, south-central China. *Acta Universitatis Stockholmsensis* 46, 1–161.
- Zhang, S. & Barnes, C.R. 2007: Late Ordovician to Early Silurian conodont faunas from the Kolyma Terrane, Omulev Mountains, northeast Russia, and their paleobiogeographic affinity. *Journal of Paleontology* 81, 490–512.
- Zhang, S., Tarrant, G.A. & Barnes, C.R. 2011: Upper Ordovician conodont biostratigraphy and age of the Collingwood Member, southern Ontario, Canada. *Canadian Journal of Earth Sciences* 48, 1497–1522.
- Zhao, Z., Zhong, G. & Xiao, J. 2000: [Palaeozoic Stratigraphy and Conodonts in Xinjiang], 334 pp. Petroleum Industry Press, Beijing, + 81 pls. (in Chinese with English summary).
- Zhen, Y.Y. & Webby, B.D. 1995: Upper Ordovician conodonts from the Cliefden Caves Limestone Group, central New South Wales, Australia. *Courier Forschungsinstitut Senckenberg* 182, 265–305.
- Zhen, Y.Y., Percival, I.G. & Webby, B.D. 2003: Early Ordovician conodonts from western New South Wales, Australia. *Records of the Australian Museum* 55, 169–220.
- Zhen, Y.Y., Percival, I.G., Cooper, R.A., Simes, J.E. & Wright, A.J. 2009: Darriwilian (Middle Ordovician) conodonts from Thompson Creek, Nelson Province, New Zealand. *Memoirs of the Association of Australasian Palaeontologists* 37, 25–53.
- Zhen, Y.Y., Wang, Z., Zhang, J.D., Bergström, S.M., Percival, I.G. & Cheng, J. 2011: Middle and Late Ordovician (Darriwilian-Sandbian) conodonts from the Dawangou section, Kalpin area of the Tarim Basin, northwestern China. *Records of the Australian Museum* 63, 203–266.
- Zhen, Y.Y., Zhang, Y., Wang, Z. & Percival, I.G. 2016: Huaiyuan epeirogeny-shaping Ordovician stratigraphy and sedimentation on the North China Platform. *Palaeogeography, Palaeoclimatology, Palaeoecology* 448, 363–370.